



Part 3: Homework

If you complete the group work, you may work on the homework on your own. This means your answers should be generally unique from other students' answers. **Submit your homework using ANGEL.**

1. Describe what it means for a reservoir to change size.
2. Describe a situation where the residence time for a reservoir in the carbon cycle is **increased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
3. Describe a situation where the residence time for a reservoir in the carbon cycle is **decreased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
4. How does an atom of carbon move from coal into the atmosphere? Explain what would happen to Earth's temperature if the processes that move carbon into the atmosphere slowed down.
5. Recall our earlier work with ocean acidification. How does an atom of carbon move from CO₂ in water into rock? How would an increase in the processes that move carbon into rock impact Earth's temperature?
6. Just for fun: How does an atom of carbon move from HCO₃ in water into carbon in your skin?

A

C. Scenario Questions

1. Imagine we rapidly uplift a large chunk of continental lithosphere to make a huge mountain range. This would expose a large volume of rocks, eventually producing small pieces of rock and chemical products, such as bicarbonate, during weathering. These weathering products make their way into streams and eventually oceans.

a. How would this uplift impact the residence time of CO_2 in the atmosphere?

There is more CO_2 present in rocks so residence time would increase.

b. Significantly more CO_2 exists in the atmosphere since the industrial revolution and the widespread use of fossil fuels. What has been the impact of this added CO_2 on the weathering rate of rocks found in mountains, monuments, and bricks?

More weathering because it is caused by CO_2 and weathering also creates CO_2 , there has been more weathering from increase in CO_2 .

2. Describe a situation where the size of a reservoir in the carbon cycle is changed and how this impacts the residence time of CO_2 throughout the entire Earth system.

If a ocean were to shrink/dry up a bit the residence time would be shorter in oceans, the residence times of other reservoirs would increase as less would be stored in oceans.

3. Describe a situation where the residence time for a reservoir in the carbon cycle is changed and how this impacts the residence time of CO_2 throughout the entire Earth system.

If you increase evaporation because of warming, the flux of a pond would increase with more going out, which would increase residence time in the atmosphere as there's more there from evaporation/deposition.

GROUP #: A

Student IDs of Members Present:

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Part 2: Group Work

A. Make sure everyone in your group understands these terms before moving on.

1. Reservoirs: *places where something is stored*
2. Evaporation: *changing liquid water to water vapor in the atmosphere*
3. Degassing: *movement of CO_2 in liquid to CO_2 in atmosphere*
4. Chemical Energy (when is energy used and when is energy released?)

B. Answer the following questions about the carbon cycle. Try to include your reasoning along with your answer – What evidence do you have to support your answer?

1. What is the largest carbon reservoir? Explain your reasoning.
Limestone, Because there is a lot of carbon on ocean floor and acidity is high.
2. Which carbon reservoir has the longest residence time? Explain your reasoning.
Limestone/rocks. Because weathering and the processes which change rock and carbon take a long time
3. Which carbon reservoir has the shortest reservoir time? Explain your reasoning.
Plants/Biosphere. They live a short life span with changes in weather so they release/take in carbon often
4. Which form of energy is more important for carbon cycle processes, gravitational or chemical? Explain your reasoning.
Chemical because most processes ~~are~~ involve a chemical change through processes like photosynthesis, respiration
5. How is the process of degassing in the carbon cycle different from the process of evaporation in the water cycle?
Degassing in carbon cycle would change CO_2 gas in water to CO_2 in air, while Evap. would change liquid to water vapor (gas)

ISP203A – Global Change Cycles

Objectives

Upon completion of this activity, you will be able to:

- Recognize how carbon moves through the environment.
- Reason about the role of different events in changing CO₂ concentrations in Earth's atmosphere
 - Reason to how this will impact temperature

Causal Principles

1. Gravitational energy, thermal energy and/or chemical energy drive all movement and change of matter on Earth.
2. A system is in equilibrium when energy in the system is balanced.
3. Matter moves and changes to return a system to equilibrium.
4. Energy is needed to break bonds and is released when bonds form.
5. Temperature is a measure of the movement of molecules. Higher temperature means molecules are moving faster.
6. When molecules move faster, the density of most substances decreases. Water is an anomaly because liquid water is more dense than ice.
7. Buoyancy causes materials to rise or fall due to the relative density of materials.
8. Feedback Loops can accelerate, decelerate, or dampen change.

PART 1: Background Notes

Part 1: Class Work

Brainstorm the important reservoirs, processes, and impacts on residence times for the carbon cycle.

Characteristic	Carbon Cycle
Reservoirs	Forests (biomas), limestone (rocks), oceans (hydrosphere), atmosphere (CO ₂ , Methane)
Processes	weathering, degassing, burial, photosynthesis, respiration burning, ocean acidification
Residence Times	Change the flux, change size of reservoir

ISP203A – Global Change
Cycles

Objectives

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PART 1: Background Notes

Part 1: Class Work

Brainstorm the important reservoirs, processes, and impacts on residence times for the carbon cycle.

Characteristic	Carbon Cycle
Reservoirs	
Processes	
Residence Times	

Part 2: Group Work

A. Make sure everyone in your group understands these terms before moving on.

1. Reservoirs:
2. Evaporation:
3. Degassing:
4. Chemical Energy (when is energy used and when is energy released?)

B. Answer the following questions about the carbon cycle. Try to include your reasoning along with your answer – What evidence do you have to support your answer?

1. What is the largest carbon reservoir? Explain your reasoning.

Limestone → rocks take up the most space and therefore it stores the most carbon
At the earth's surface, the biosphere

2. Which carbon reservoir has the longest residence time? Explain your reasoning.

Lithosphere because of burial. Carbon is sitting

3. Which carbon reservoir has the shortest reservoir time? Explain your reasoning.

Biosphere because organisms are passing carbon through photosynthesis + respiration

4. Which form of energy is more important for carbon cycle processes, gravitational or chemical? Explain your reasoning.

Chemical → in order for photosynthesis, respiration, degassing or other ways to release carbon / store carbon, chemical energy is used

5. How is the process of degassing in the carbon cycle different from the process of evaporation in the water cycle?

Degassing - carbon is going from gas in the hydrosphere to gas in the atmosphere whereas evaporation is a liquid transforming to a gas in the atmosphere.

B

C. Scenario Questions

1. Imagine we rapidly uplift a large chunk of continental lithosphere to make a huge mountain range. This would expose a large volume of rocks, eventually producing small pieces of rock and chemical products, such as bicarbonate, during weathering. These weathering products make their way into streams and eventually oceans.

a. How would this uplift impact the residence time of CO₂ in the atmosphere?
weathering would create more carbon in the hydrosphere and atmosphere which would shorten the residence time.

- b. Significantly more CO₂ exists in the atmosphere since the industrial revolution and the widespread use of fossil fuels. What has been the impact of this added CO₂ on the weathering rate of rocks found in mountains, monuments, and bricks?

As CO₂ concentrations increase, weathering increases because water in the presence of CO₂ weathers material

2. Describe a situation where the size of a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

Deforestation decreases size of reservoir and because those trees store a lot of carbon, when trees are cut, the levels of CO₂ in the atmosphere are increased

3. Describe a situation where the residence time for a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

Deforestation would mean that CO₂ could not be taken up any other way and therefore the residence time would increase in the atmosphere.



Part 3: Homework

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3. Describe a situation where the residence time for a reservoir in the carbon cycle is **decreased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
4. How does an atom of carbon move from coal into the atmosphere? Explain what would happen to Earth's temperature if the processes that move carbon into the atmosphere slowed down.
5. Recall our earlier work with ocean acidification. How does an atom of carbon move from CO₂ in water into rock? How would an increase in the processes that move carbon into rock impact Earth's temperature?
6. Just for fun: How does an atom of carbon move from HCO₃ in water into carbon in your skin?

ISP203A – Global Change Cycles

C

Objectives

Upon completion of this activity, you will be able to:

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Causal Principles

1. Gravitational energy, thermal energy and/or chemical energy drive all movement and change of matter on Earth.
2. A system is in equilibrium when energy in the system is balanced.
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PART 1: Background Notes

Different carbon → way about different material its in, not just phase

Part 1: Class Work

Brainstorm the important reservoirs, processes, and impacts on residence times for the carbon cycle.

Characteristic	Carbon Cycle
Reservoirs	Forests (biosphere), Limestone (Rock), oceans (hydrosphere), Gas - (CO ₂) atmosphere
Processes	Weathering, Degassing, burial, Photosynthesis, Respiration, burning, Ocean Acidification
Residence Times	Change flux, change size reservoir will impact all others, decreasing reservoir will decrease residence time, decreasing flux will increase residence time

*reservoir will decrease
residence time*

Part 2: Group Work

A. Make sure everyone in your group understands these terms before moving on.

1. Reservoirs: ✓

2. Evaporation: ✓

3. Degassing: ✓

4. Chemical Energy (when is energy used and when is energy released?)

B. Answer the following questions about the carbon cycle. Try to include your reasoning along with your answer – What evidence do you have to support your answer?

1. What is the largest carbon reservoir? Explain your reasoning.

Limestone. As more carbon enters the water, it breaks down and will eventually form limestone or shells that get buried into a rock reservoir.

2. Which carbon reservoir has the longest residence time? Explain your reasoning.

Carbonate rock, which is just sedimentary rock like limestone from the longest residence time because for most of their life, the carbon just builds up, layers upon layers and is buried.

3. Which carbon reservoir has the shortest reservoir time? Explain your reasoning.

The atmosphere where CO_2 is the carbon type has the shortest residence time because it is released as CO_2 and either escapes the atmosphere or quickly converts to something else.

4. Which form of energy is more important for carbon cycle processes, gravitational or chemical? Explain your reasoning.

Chemical, because carbon is already present in so many form and without chemical you couldn't change the state. Gravitational energy doesn't have as much importance.

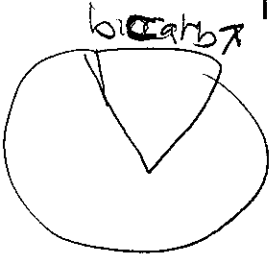
5. How is the process of degassing in the carbon cycle different from the process of evaporation in the water cycle?

Degassing in the carbon cycle deals with carbon dioxide (in gas form) leaving the hydrosphere and entering the atmosphere still as CO_2 in gas form. Evaporation deals with water in the phase of liquid going to water as a gas in the atmosphere.

C

C. Scenario Questions

1. Imagine we rapidly uplift a large chunk of continental lithosphere to make a huge mountain range. This would expose a large volume of rocks, eventually producing small pieces of rock and chemical products, such as bicarbonate, during weathering. These weathering products make their way into streams and eventually oceans.



- a. How would this uplift impact the residence time of CO₂ in the atmosphere?

Uplift would increase the amount in the atmosphere and therefore increase the residence time of carbon in all reservoirs (including the atmosphere)

- b. Significantly more CO₂ exists in the atmosphere since the industrial revolution and the widespread use of fossil fuels. What has been the impact of this added CO₂ on the weathering rate of rocks found in mountains, monuments, and bricks?

Added CO₂ in the atmosphere increases the weathering rate of rocks since Carbon plays a vital role in weathering.

2. Describe a situation where the size of a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

If the size of a reservoir, like the atmosphere, is increased, the residence times of CO₂ throughout the Earth system would also increase. Adding CO₂ to the atmosphere would further greenhouse gas warming and heat up oceans & melt ice, which would then increase the amount of ocean acidification

3. Describe a situation where the residence time for a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system. and change carbon in every reservoir & system.

If the above situation occurred and subsequently the residence time increased, (in regard to the atmosphere), then the Earth system would also have higher temperatures and ocean acidification & degassing and weathering would occur more quickly.



Part 3: Homework

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2. Describe a situation where the residence time for a reservoir in the carbon cycle is **increased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
3. Describe a situation where the residence time for a reservoir in the carbon cycle is **decreased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
4. How does an atom of carbon move from coal into the atmosphere? Explain what would happen to Earth's temperature if the processes that move carbon into the atmosphere slowed down.
5. Recall our earlier work with ocean acidification. How does an atom of carbon move from CO₂ in water into rock? How would an increase in the processes that move carbon into rock impact Earth's temperature?
6. Just for fun: How does an atom of carbon move from HCO₃ in water into carbon in your skin?



Objectives

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 - Reason to how this will impact temperature

Causal Principles

1. Gravitational energy, thermal energy and/or chemical energy drive all movement and change of matter on Earth.
2. A system is in equilibrium when energy in the system is balanced.
3. Matter moves and changes to return a system to equilibrium.
4. Energy is needed to break bonds and is released when bonds form.
5. Temperature is a measure of the movement of molecules. Higher temperature means molecules are moving faster.
6. When molecules move faster, the density of most substances decreases. Water is an anomaly because liquid water is more dense than ice.
7. Buoyancy causes materials to rise or fall due to the relative density of materials.
8. Feedback Loops can accelerate, decelerate, or dampen change.

PART 1: Background Notes

Part 1: Class Work

Brainstorm the important reservoirs, processes, and impacts on residence times for the carbon cycle.

Characteristic	Carbon Cycle
Reservoirs	
Processes	
Residence Times	

Part 2: Group Work

A. Make sure everyone in your group understands these terms before moving on.

1. Reservoirs: places where materials are held (ex. oceans, atmosphere, carbon, calcium, rocks)
2. Evaporation: change from liquid \rightarrow gas
3. Degassing: movement of gas from one reservoir to another
4. Chemical Energy (when is energy used and when is energy released?)
change of arrangement of molecules
break bonds - energy required form bonds - energy released

B. Answer the following questions about the carbon cycle. Try to include your reasoning along with your answer – What evidence do you have to support your answer?

1. What is the largest carbon reservoir? Explain your reasoning.

Biosphere because plants sequester the most carbon & there is more diversity of plants in the biosphere than the

2. Which carbon reservoir has the longest residence time? Explain your reasoning. hydrosphere
Hydrosphere because it remains buried in the rocks until something/someone disrupts it.

3. Which carbon reservoir has the shortest reservoir time? Explain your reasoning.

atmosphere because its constantly moving & changing from the biosphere & hydrosphere.

4. Which form of energy is more important for carbon cycle processes, gravitational or chemical? Explain your reasoning.

chemical because carbon exists in so many different compounds.

5. How is the process of degassing in the carbon cycle different from the process of evaporation in the water cycle?

~~deg~~ carbon exists as a gas in the ocean & remains a gas as it is "degassed" into the atmosphere while water is in liquid form in the ocean & becomes a gas during evaporation into the atmosphere.

D

C. Scenario Questions

1. Imagine we rapidly uplift a large chunk of continental lithosphere to make a huge mountain range. This would expose a large volume of rocks, eventually producing small pieces of rock and chemical products, such as bicarbonate, during weathering. These weathering products make their way into streams and eventually oceans.

a. How would this uplift impact the residence time of CO₂ in the atmosphere?

It would increase it because the ~~rock~~ ^{CO₂} is ~~longer~~ being held under the surface but can now be released into the atmosphere as ~~leech rock~~.

b. Significantly more CO₂ exists in the atmosphere since the industrial revolution and the widespread use of fossil fuels. What has been the impact of this added CO₂ on the weathering rate of rocks found in mountains, monuments, and bricks?

Increasing weathering as CO₂ in the atmosphere ~~inter~~ causes more CO₂ in and rain

2. Describe a situation where the size of a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

If you decrease the size of a ~~reservoir~~ lake by building a dam for hydroelectric power, the water left would evaporate much faster, speeding up all other processes.

3. Describe a situation where the residence time for a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

The flux is changed if a river is connected to a lake, bringing more water in, increasing residence time of the lake, slowing all other processes.

D

Part 3: Homework

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1. Describe what it means for a reservoir to change size.
2. Describe a situation where the residence time for a reservoir in the carbon cycle is **increased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
3. Describe a situation where the residence time for a reservoir in the carbon cycle is **decreased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
4. How does an atom of carbon move from coal into the atmosphere? Explain what would happen to Earth's temperature if the processes that move carbon into the atmosphere slowed down.
5. Recall our earlier work with ocean acidification. How does an atom of carbon move from CO₂ in water into rock? How would an increase in the processes that move carbon into rock impact Earth's temperature?
6. Just for fun: How does an atom of carbon move from HCO₃ in water into carbon in your skin?

E

ISP203A – Global Change Cycles

Objectives

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Causal Principles

1. Gravitational energy, thermal energy and/or chemical energy drive all movement and change of matter on Earth.
2. A system is in equilibrium when energy in the system is balanced.
3. Matter moves and changes to return a system to equilibrium.
4. Energy is needed to break bonds and is released when bonds form.
5. Temperature is a measure of the movement of molecules. Higher temperature means molecules are moving faster.
6. When molecules move faster, the density of most substances decreases. Water is an anomaly because liquid water is more dense than ice.
7. Buoyancy causes materials to rise or fall due to the relative density of materials.
8. Feedback Loops can accelerate, decelerate, or dampen change.

PART 1: Background Notes

Part 1: Class Work

Brainstorm the important reservoirs, processes, and impacts on residence times for the carbon cycle.

Characteristic	Carbon Cycle
Reservoirs	Fossil fuels (biosphere), limestone (rocks, CaCO ₃), oceans (hydrosphere; gas - CO ₂ , CO ₃ , HCO ₃), atmosphere
Processes	weathering, degassing, burial, photosynthesis, respiration, burning, ocean acidification
Residence Times	change flux, size of reservoirs. ↓ reservoir you ↓ residence time. ↓ residence flux into reservoir then you ↑ the residence time out of

GROUP #:

Student IDs of Members Present:

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~~XXXXXXXXXX~~ A42190700

~~XXXXXXXXXX~~ A41503028

Part 2: Group Work

A. Make sure everyone in your group understands these terms before moving on.

1. Reservoirs: places where water is stored (or carbon)
2. Evaporation: changing from a liquid to a gas.
3. Degassing: movement from gas from one reservoir to another.
4. Chemical Energy (when is energy used and when is energy released?)
used when it makes bonds and released when bonds are formed.

B. Answer the following questions about the carbon cycle. Try to include your reasoning along with your answer – What evidence do you have to support your answer?

1. What is the largest carbon reservoir? Explain your reasoning.
Limestone because it is made of all the dead organic matter.
2. Which carbon reservoir has the longest residence time? Explain your reasoning.
Atmosphere because it gets trapped and it also moves in and out. The largest reservoir has the longest residence time.
3. Which carbon reservoir has the shortest reservoir time? Explain your reasoning.
Biomass because it's the smallest reservoir, the smallest reservoir has the shortest residence time.
4. Which form of energy is more important for carbon cycle processes, gravitational or chemical? Explain your reasoning.
Chemical energy. because there is more phase changes that use chemical energy than gravitational energy.
5. How is the process of degassing in the carbon cycle different from the process of evaporation in the water cycle?

Degassing is a gas going from one reservoir to another, and evaporation is changing from liquid to gas.

E

C. Scenario Questions

1. Imagine we rapidly uplift a large chunk of continental lithosphere to make a huge mountain range. This would expose a large volume of rocks, eventually producing small pieces of rock and chemical products, such as bicarbonate, during weathering. These weathering products make their way into streams and eventually oceans.

- a. How would this uplift impact the residence time of CO₂ in the atmosphere?

It will be eroded and weathered. In order to weather rocks you use CO₂ by pulling it out of the rocks and releasing CO₂ into the atmosphere. same

- b. Significantly more CO₂ exists in the atmosphere since the industrial revolution and the widespread use of fossil fuels. What has been the impact of this added CO₂ on the weathering rate of rocks found in mountains, monuments, and bricks?

The more CO₂ in the atmosphere, the more acid rain there is, therefore more weathering of rocks, and run it cycles.

2. Describe a situation where the size of a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

There is a pond and it dries up, so the residence time ~~disappears~~ shortens for the water, so the residence time for the atmosphere and biosphere gets longer.

3. Describe a situation where the residence time for a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

There is a lake that is by a stream, and the stream starts flowing faster so the flux is greater making the residence time less in the lake.

ISP203A – Global Change
Cycles

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Causal Principles

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PART 1: Background Notes

Part 1: Class Work

Brainstorm the important reservoirs, processes, and impacts on residence times for the carbon cycle.

Characteristic	Carbon Cycle
Reservoirs	atmosphere, biomass, lithosphere, hydrosphere, biosphere
Processes	weathering, Burial, metamorphism, subduction, volcanic, Degassing, burning, ocean acidification,
Residence Times	

A42766836 A43864729
A42385484

Part 2: Group Work

A. Make sure everyone in your group understands these terms before moving on.

1. Reservoirs: *places where substances are held.*
2. Evaporation: *liquid to gas*
3. Degassing: *a gas moving through a liquid to the air.*
4. Chemical Energy (when is energy used and when is energy released?)
Energy used or released from chemical reactions.

B. Answer the following questions about the carbon cycle. Try to include your reasoning along with your answer – What evidence do you have to support your answer?

1. What is the largest carbon reservoir? Explain your reasoning.
Biosphere because carbon particles are tightly packed together
2. Which carbon reservoir has the longest residence time? Explain your reasoning.
Biosphere because the carbon is so tightly packed.
3. Which carbon reservoir has the shortest reservoir time? Explain your reasoning.
hydrosphere, more processes take place in the hydrosphere than in other reservoirs.
4. Which form of energy is more important for carbon cycle processes, gravitational or chemical? Explain your reasoning.
Chemical, more processes in the cycle use chemical energy, ocean acidification, weathering, metamorphism.
5. How is the process of degassing in the carbon cycle different from the process of evaporation in the water cycle?
The carbon is not changing state.

F

C. Scenario Questions

1. Imagine we rapidly uplift a large chunk of continental lithosphere to make a huge mountain range. This would expose a large volume of rocks, eventually producing small pieces of rock and chemical products, such as bicarbonate, during weathering. These weathering products make their way into streams and eventually oceans.

- a. How would this uplift impact the residence time of CO₂ in the atmosphere?

It would increase the residence time because of weathering.

- b. Significantly more CO₂ exists in the atmosphere since the industrial revolution and the widespread use of fossil fuels. What has been the impact of this added CO₂ on the weathering rate of rocks found in mountains, monuments, and bricks?

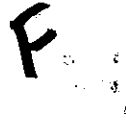
Weathering has increased because water and CO₂ create acid which weathers down rocks. There is more CO₂ in the atmosphere so there will be more reactions to make acids.

2. Describe a situation where the size of a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

Deforestation has effected the carbon cycle because less trees are using CO₂ and more weathering has occurred.

3. Describe a situation where the residence time for a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

The use of fossil fuels has increased the amount of CO₂ in the atmosphere and has decreased the residence time in mountains and other rocks because of an increase in weathering.



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4. How does an atom of carbon move from coal into the atmosphere? Explain what would happen to Earth's temperature if the processes that move carbon into the atmosphere slowed down.
5. Recall our earlier work with ocean acidification. How does an atom of carbon move from CO₂ in water into rock? How would an increase in the processes that move carbon into rock impact Earth's temperature?
6. Just for fun: How does an atom of carbon move from HCO₃ in water into carbon in your skin?

ISP203A – Global Change Cycles

Objectives

Upon completion of this activity, you will be able to:

- Recognize how carbon moves through the environment.
- Reason about the role of different events in changing CO₂ concentrations in Earth's atmosphere
 - Reason to how this will impact temperature

Causal Principles

1. Gravitational energy, thermal energy and/or chemical energy drive all movement and change of matter on Earth.
2. A system is in equilibrium when energy in the system is balanced.
3. Matter moves and changes to return a system to equilibrium.
4. Energy is needed to break bonds and is released when bonds form.
5. Temperature is a measure of the movement of molecules. Higher temperature means molecules are moving faster.
6. When molecules move faster, the density of most substances decreases. Water is an anomaly because liquid water is more dense than ice.
7. Buoyancy causes materials to rise or fall due to the relative density of materials.
8. Feedback Loops can accelerate, decelerate, or dampen change.

PART 1: Background Notes

Part 1: Class Work

Brainstorm the important reservoirs, processes, and impacts on residence times for the carbon cycle.

Characteristic	Carbon Cycle
Reservoirs	atmosphere, hydrosphere, biosphere, lithosphere forests (biomass), limestone (rocks), Oceans
Processes	weathering, erosion, sedimentation , ocean acidification, respiration, burning weathering, evaporation, degassing, burial, photosynthesis
Residence Times	change flux, change size of reservoir decrease reservoir = decrease res. time decrease flux = increase res. time

A42235241
A413018410
A413018410

GROUP #: 
Student IDs of Members Present:

A40659708
A40737921

Part 2: Group Work

A. Make sure everyone in your group understands these terms before moving on.

1. Reservoirs: a place where water is stored
2. Evaporation: the process of water molecules moving into the atmosphere as water vapor by thermal energy
3. Degassing: removal of dissolved gases from liquids
4. Chemical Energy (when is energy used and when is energy released?) transformation through a chemical reaction.

B. Answer the following questions about the carbon cycle. Try to include your reasoning along with your answer – What evidence do you have to support your answer?

1. What is the largest carbon reservoir? Explain your reasoning.

Biosphere (most carbon)

2. Which carbon reservoir has the longest residence time? Explain your reasoning.

Lithosphere - solid molecules ~~move~~ move slower than liquid or gas.

3. Which carbon reservoir has the shortest reservoir time? Explain your reasoning.

Atmosphere - ↑

4. Which form of energy is more important for carbon cycle processes, gravitational or chemical? Explain your reasoning.

Chemical - ~~is~~ Carbon has many different forms in the carbon cycle (HCO_3^- , CO_2 , CaCO_3) and changes more often than say the water in

5. How is the process of degassing in the carbon cycle different from the process of the evaporation in the water cycle?

Degassing isn't changing chemically (stays CO_2) gas escaping

Evaporation is H_2O to water vapor (liquid to gas)



C. Scenario Questions

1. Imagine we rapidly uplift a large chunk of continental lithosphere to make a huge mountain range. This would expose a large volume of rocks, eventually producing small pieces of rock and chemical products, such as bicarbonate, during weathering. These weathering products make their way into streams and eventually oceans.

- a. How would this uplift impact the residence time of CO₂ in the atmosphere?

uplift & weathering increases CO₂ into the atmosphere, more CO₂ = ↑ residence time

- b. Significantly more CO₂ exists in the atmosphere since the industrial revolution and the widespread use of fossil fuels. What has been the impact of this added CO₂ on the weathering rate of rocks found in mountains, monuments, and bricks?

↑ weathering due to precipitation from inc. CO₂ (greenhouse gasses) in atmosphere

2. Describe a situation where the size of a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.
3. Describe a situation where the residence time for a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.



Part 3: Homework

If you complete the group work, you may work on the homework **on your own**. This means your answers should be generally unique from other students' answers. **Submit your homework using ANGEL.**

1. Describe what it means for a reservoir to change size.

The flux in/out determines the size
(how much of the matter is in it)

2. Describe a situation where the residence time for a reservoir in the carbon cycle is **increased** and how this impacts the residence time of CO₂ throughout the entire Earth system.

Deforestation - burning
↑ carbon in atmosphere, ↑ residence time

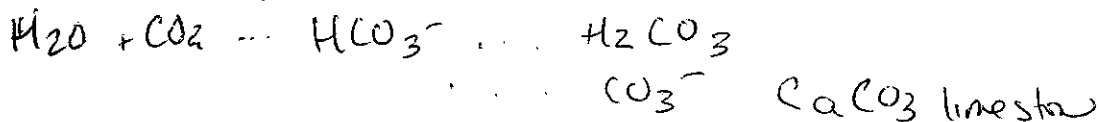
3. Describe a situation where the residence time for a reservoir in the carbon cycle is **decreased** and how this impacts the residence time of CO₂ throughout the entire Earth system.

An increase in plants - use up CO₂ in atmosphere
↓ residence time of C in atmosphere.

4. How does an atom of carbon move from coal into the atmosphere? Explain what would happen to Earth's temperature if the processes that move carbon into the atmosphere slowed down.

Burn coal → CO₂ in atmosphere
If it slowed down the residence size would dec.
and the temp would cool down (less CO₂ in atmosp.)

5. Recall our earlier work with ocean acidification. How does an atom of carbon move from CO₂ in water into rock? How would an increase in the processes that move carbon into rock impact Earth's temperature?



6. Just for fun: How does an atom of carbon move from HCO₃ in water into carbon in your skin?

HCO₃⁻ in water

CaCO₃ in turns

or... rain drop hits rock
gives off CO₂

plant uses CO₂ → we eat plant

H

~~Handwritten notes, mostly illegible due to heavy blacking out.~~

Objectives

Upon completion of this activity, you will be able to:

- Recognize how carbon moves through the environment.
- Reason about the role of different events in changing CO₂ concentrations in Earth's atmosphere
 - Reason to how this will impact temperature

Causal Principles

1. Gravitational energy, thermal energy and/or chemical energy drive all movement and change of matter on Earth.
2. A system is in equilibrium when energy in the system is balanced.
3. Matter moves and changes to return a system to equilibrium.
4. Energy is needed to break bonds and is released when bonds form.
5. Temperature is a measure of the movement of molecules. Higher temperature means molecules are moving faster.
6. When molecules move faster, the density of most substances decreases. Water is an anomaly because liquid water is more dense than ice.
7. Buoyancy causes materials to rise or fall due to the relative density of materials.
8. Feedback Loops can accelerate, decelerate, or dampen change.

PART 1: Background Notes

Part 1: Class Work

Brainstorm the important reservoirs, processes, and impacts on residence times for the carbon cycle.

Characteristic	Carbon Cycle
Reservoirs	Forests (Biomass), Limestone (rocks), Oceans (hydrosphere), atmosphere (CO ₂ methane)
Processes	Weathering, Degassing, Burial, photosynthesis, Respiration, Burning, Ocean Acidification.
Residence Times	change flux, change size, decrease reservoir size. decrease flux decrease RT.

Part 2: Group Work

A. Make sure everyone in your group understands these terms before moving on.

1. Reservoirs: Location of matter.
2. Evaporation: change of a liquid to a gas.
3. Degassing: The change in location of a gas.
4. Chemical Energy (when is energy used and when is energy released?)

B. Answer the following questions about the carbon cycle. Try to include your reasoning along with your answer – What evidence do you have to support your answer?

1. What is the largest carbon reservoir? Explain your reasoning.

Ocean, because water ~~is the largest~~ ^{consumes} most of the earth. (Biosphere) ^{most carbon consumed}

2. Which carbon reservoir has the longest residence time? Explain your reasoning.

~~Rocks~~ ^{slowly} Ocean. Carbon has more processes that ~~associate~~ ^{associate} with water so perhaps it would take longer. ^{Biosphere}

3. Which carbon reservoir has the shortest reservoir time? Explain your reasoning.

~~Atmosphere~~ ^{Biosphere} ~~less processes~~ ^{more}

4. Which form of energy is more important for carbon cycle processes, gravitational or chemical? Explain your reasoning.

^{Quick processes} Chemical, changing forms more than location.

5. How is the process of degassing in the carbon cycle different from the process of evaporation in the water cycle?

In evaporation matters change in form. But in degassing its form doesn't change only its location.

3

H

C. Scenario Questions

1. Imagine we rapidly uplift a large chunk of continental lithosphere to make a huge mountain range. This would expose a large volume of rocks, eventually producing small pieces of rock and chemical products, such as bicarbonate, during weathering. These weathering products make their way into streams and eventually oceans.

a. How would this uplift impact the residence time of CO₂ in the atmosphere?

- b. Significantly more CO₂ exists in the atmosphere since the industrial revolution and the widespread use of fossil fuels. What has been the impact of this added CO₂ on the weathering rate of rocks found in mountains, monuments, and bricks?

More formation of carbonic acid will cause an increase in weathering.

2. Describe a situation where the size of a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

3. Describe a situation where the residence time for a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

If the residence time of different water reservoirs were to change it would have a huge effect on the atmospheric cycle.

A

Part 3: Homework

If you complete the group work, you may work on the homework on your own. This means your answers should be generally unique from other students' answers. **Submit your homework using ANGEL.**

1. Describe what it means for a reservoir to change size.
2. Describe a situation where the residence time for a reservoir in the carbon cycle is **increased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
3. Describe a situation where the residence time for a reservoir in the carbon cycle is **decreased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
4. How does an atom of carbon move from coal into the atmosphere? Explain what would happen to Earth's temperature if the processes that move carbon into the atmosphere slowed down.
5. Recall our earlier work with ocean acidification. How does an atom of carbon move from CO₂ in water into rock? How would an increase in the processes that move carbon into rock impact Earth's temperature?
6. Just for fun: How does an atom of carbon move from HCO₃ in water into carbon in your skin?

ISP203A – Global Change Cycles

I

Objectives

Upon completion of this activity, you will be able to:

- Recognize how carbon moves through the environment.
- Reason about the role of different events in changing CO₂ concentrations in Earth's atmosphere
 - Reason to how this will impact temperature

Causal Principles

1. Gravitational energy, thermal energy and/or chemical energy drive all movement and change of matter on Earth.
2. A system is in equilibrium when energy in the system is balanced.
3. Matter moves and changes to return a system to equilibrium.
4. Energy is needed to break bonds and is released when bonds form.
5. Temperature is a measure of the movement of molecules. Higher temperature means molecules are moving faster.
6. When molecules move faster, the density of most substances decreases. Water is an anomaly because liquid water is more dense than ice.
7. Buoyancy causes materials to rise or fall due to the relative density of materials.
8. Feedback Loops can accelerate, decelerate, or dampen change.

PART 1: Background Notes

Part 1: Class Work

Brainstorm the important reservoirs, processes, and impacts on residence times for the carbon cycle.

Characteristic	Carbon Cycle
Reservoirs	
Processes	
Residence Times	

Part 2: Group Work

A. Make sure everyone in your group understands these terms before moving on.

1. Reservoirs: Place or area where matter is stored.
2. Evaporation: Changing from a liquid to a gas
3. Degassing: Movement of a gas from one reservoir to another
4. Chemical Energy (when is energy used and when is energy released?)
Energy stored and released from the forming & breaking of bonds.

B. Answer the following questions about the carbon cycle. Try to include your reasoning along with your answer – What evidence do you have to support your answer?

1. What is the largest carbon reservoir? Explain your reasoning.

Lithosphere is the largest carbon reservoir. This is because carbon is found in many areas here. (limestone and CO₂) and in mass quantities.

2. Which carbon reservoir has the longest residence time? Explain your reasoning.

The lithosphere has the longest residence time because there is a short flux, but it's also a very large reservoir.

3. Which carbon reservoir has the shortest reservoir time? Explain your reasoning.

The atmosphere has the shortest reservoir time. This is because it has a high flux; CO₂ in the atmosphere is constantly moving in and out.

4. Which form of energy is more important for carbon cycle processes, gravitational or chemical? Explain your reasoning.

Chemical energy is most important for carbon cycle processes. This is because carbon is constantly changing form in terms of molecules. Rarely does it stay as just carbon.

5. How is the process of degassing in the carbon cycle different from the process of evaporation in the water cycle?

Degassing in carbon cycle is different from the process of evaporation in the water cycle because there is no phase change. It remains a gas versus evaporation where it goes from a liquid to a gas.

I

C. Scenario Questions

1. Imagine we rapidly uplift a large chunk of continental lithosphere to make a huge mountain range. This would expose a large volume of rocks, eventually producing small pieces of rock and chemical products, such as bicarbonate, during weathering. These weathering products make their way into streams and eventually oceans.

- a. How would this uplift impact the residence time of CO_2 in the atmosphere?

This uplift would increase the residence time of CO_2 in the atmosphere. This is because the reservoir size is staying the same, but the flux in is increasing.

- b. Significantly more CO_2 exists in the atmosphere since the industrial revolution and the widespread use of fossil fuels. What has been the impact of this added CO_2 on the weathering rate of rocks found in mountains, monuments, and bricks?

The added CO_2 in the atmosphere has caused an increase on the weathering rate of rocks. This is because as rain becomes more acidic, due to the increased CO_2 , it causes weathering to increase.

2. Describe a situation where the size of a reservoir in the carbon cycle is changed and how this impacts the residence time of CO_2 throughout the entire Earth system.

Deforestation, or cutting down forest in the biomass, will cause residence times of CO_2 in the entire Earth system to increase. If there is less of the reservoir, that CO_2 is added to the other reservoirs, increasing their residence times.

3. Describe a situation where the residence time for a reservoir in the carbon cycle is changed and how this impacts the residence time of CO_2 throughout the entire Earth system.

With the increase of CO_2 into the environment from humans, this will cause residence time to decrease in the atmosphere. As the CO_2 moves faster in, it will also move faster out. This will cause other reservoirs connected to the atmosphere to also have a decrease in reservoir times.

I

Part 3: Homework

If you complete the group work, you may work on the homework on your own. This means your answers should be generally unique from other students' answers. **Submit your homework using ANGEL.**

1. Describe what it means for a reservoir to change size.
2. Describe a situation where the residence time for a reservoir in the carbon cycle is **increased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
3. Describe a situation where the residence time for a reservoir in the carbon cycle is **decreased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
4. How does an atom of carbon move from coal into the atmosphere? Explain what would happen to Earth's temperature if the processes that move carbon into the atmosphere slowed down.
5. Recall our earlier work with ocean acidification. How does an atom of carbon move from CO₂ in water into rock? How would an increase in the processes that move carbon into rock impact Earth's temperature?
6. Just for fun: How does an atom of carbon move from HCO₃ in water into carbon in your skin?

ISP203A – Global Change Cycles

Objectives

Upon completion of this activity, you will be able to:

- Recognize how carbon moves through the environment.
- Reason about the role of different events in changing CO₂ concentrations in Earth's atmosphere
 - Reason to how this will impact temperature

Causal Principles

1. Gravitational energy, thermal energy and/or chemical energy drive all movement and change of matter on Earth.
2. A system is in equilibrium when energy in the system is balanced.
3. Matter moves and changes to return a system to equilibrium.
4. Energy is needed to break bonds and is released when bonds form.
5. Temperature is a measure of the movement of molecules. Higher temperature means molecules are moving faster.
6. When molecules move faster, the density of most substances decreases. Water is an anomaly because liquid water is more dense than ice.
7. Buoyancy causes materials to rise or fall due to the relative density of materials.
8. Feedback Loops can accelerate, decelerate, or dampen change.

PART 1: Background Notes

Part 1: Class Work

Brainstorm the important reservoirs, processes, and impacts on residence times for the carbon cycle.

Characteristic	Carbon Cycle
Reservoirs	Forests, limestone, oceans atmosphere, biosphere, lithosphere. (CO ₂ , CaCO ₃ , HCO ₃ ²⁻)
Processes	weathering, degassing, burial, burning, acidification
Residence Times	change time, decrease or increase size of reservoir, flux is decreased then residence time is increased.

Part 2: Group Work

A. Make sure everyone in your group understands these terms before moving on.

1. Reservoirs: where carbon is stored.

2. Evaporation: the process when a liquid is changed into a gas.

3. Degassing: the movement of gas from one place to another.

4. Chemical Energy (when is energy used and when is energy released?)

chem energy is used to weather rocks (carbon is released)
chem energy is released when carbon breaks down from broken bonds

B. Answer the following questions about the carbon cycle. Try to include your reasoning along with your answer – What evidence do you have to support your answer?

1. What is the largest carbon reservoir? Explain your reasoning. (biosphere)

The largest carbon reservoir is in rocks or limestone because they are able to hold the largest concentration of carbon.

2. Which carbon reservoir has the longest residence time? Explain your reasoning.

Rocks have the longest residence time because it takes a long time and a lot of energy to break down rocks.

3. Which carbon reservoir has the shortest reservoir time? Explain your reasoning.

The atmosphere has the shortest residence time for carbon because the carbon moves more quickly in the atmosphere.

4. Which form of energy is more important for carbon cycle processes, gravitational or chemical? Explain your reasoning.

Chemical energy is more important for carbon cycle processes because there are a lot of changes and forms of carbon present in the carbon cycle.

5. How is the process of degassing in the carbon cycle different from the process of evaporation in the water cycle?

Degassing in the carbon cycle is when carbon gas is moved from one place to another place and evaporation in the water cycle involves change of state of water molecules or form.

J

C. Scenario Questions

1. Imagine we rapidly uplift a large chunk of continental lithosphere to make a huge mountain range. This would expose a large volume of rocks, eventually producing small pieces of rock and chemical products, such as bicarbonate, during weathering. These weathering products make their way into streams and eventually oceans.

a. How would this uplift impact the residence time of CO₂ in the atmosphere?

This uplift would increase the residence time because more CO₂ would be released into the atmosphere.

b. Significantly more CO₂ exists in the atmosphere since the industrial revolution and the widespread use of fossil fuels. What has been the impact of this added CO₂ on the weathering rate of rocks found in mountains, monuments, and bricks?

The rocks weather faster because the CO₂ makes the rain more acidic.

2. Describe a situation where the size of a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

More CO₂ in the ocean causes the ocean to become more acidic, which breaks down the coral reef releasing more CO₂ into the atmosphere.

3. Describe a situation where the residence time for a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

Putting more CO₂ into the atmosphere would increase the residence time, which would increase the residence time throughout the entire Earth system.

Part 3: Homework

If you complete the group work, you may work on the homework on your own. This means your answers should be generally unique from other students' answers. **Submit your homework using ANGEL.**

1. Describe what it means for a reservoir to change size.
2. Describe a situation where the residence time for a reservoir in the carbon cycle is **increased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
3. Describe a situation where the residence time for a reservoir in the carbon cycle is **decreased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
4. How does an atom of carbon move from coal into the atmosphere? Explain what would happen to Earth's temperature if the processes that move carbon into the atmosphere slowed down.
5. Recall our earlier work with ocean acidification. How does an atom of carbon move from CO₂ in water into rock? How would an increase in the processes that move carbon into rock impact Earth's temperature?
6. Just for fun: How does an atom of carbon move from HCO₃ in water into carbon in your skin?

K

Objectives

Upon completion of this activity, you will be able to:

- Recognize how carbon moves through the environment.
- Reason about the role of different events in changing CO₂ concentrations in Earth's atmosphere
 - Reason to how this will impact temperature

Causal Principles

1. Gravitational energy, thermal energy and/or chemical energy drive all movement and change of matter on Earth.
2. A system is in equilibrium when energy in the system is balanced. *energy*
3. Matter moves and changes to return a system to equilibrium.
4. Energy is needed to break bonds and is released when bonds form.
5. Temperature is a measure of the movement of molecules. Higher temperature means molecules are moving faster.
6. When molecules move faster, the density of most substances decreases. Water is an anomaly because liquid water is more dense than ice.
7. Buoyancy causes materials to rise or fall due to the relative density of materials.
8. Feedback Loops can accelerate, decelerate, or dampen change.

PART 1: Background Notes

weathering → uses CO₂ & produces CO₂
Calcium Carbonate = Limestone / shells

Part 1: Class Work

Brainstorm the important reservoirs, processes, and impacts on residence times for the carbon cycle.

Characteristic	Carbon Cycle
Reservoirs <i>HCO₃ CO₂ CO₃ →</i>	<i>forests, biomass (organism), rock (limestone), oceans, Atmosphere (gas), biosphere, lithosphere.</i>
Processes	<i>weathering, degassing, burial, acidification Photosynthesis, respiration, burning</i>
Residence Times	<i>change size, change flux, decrease time. decrease residence time.</i>

Part 2: Group Work

A. Make sure everyone in your group understands these terms before moving on.

1. Reservoirs:

A place that stores CO₂.

2. Evaporation: when a liquid transform into a gas

3. Degassing:

when a gas in the ocean moves into the atmosphere.

4. Chemical Energy (when is energy used and when is energy released?)

Used to create equilibrium

B. Answer the following questions about the carbon cycle. Try to include your reasoning along with your answer – What evidence do you have to support your answer?

1. What is the largest carbon reservoir? Explain your reasoning.

The ocean, because exist in many different forms. And oceans consume much of the earth (limestone)

2. Which carbon reservoir has the longest residence time? Explain your reasoning.

Rock would have the longest because it takes the longest form & to weather. The flux in & out is small.

3. Which carbon reservoir has the shortest reservoir time? Explain your reasoning.

The shortest would be the biosphere / Plants. Cause photosynthesis occurs very often. the biosphere has a high flux.

4. Which form of energy is more important for carbon cycle processes, gravitational or chemical? Explain your reasoning.

Chemical energy is the most important because many processes occur due to chemical energy.

5. How is the process of degassing in the carbon cycle different from the process of evaporation in the water cycle?

degassing the gas doesn't change form it stay a gas. in evaporation a liquid water turns into a gas.



C. Scenario Questions

1. Imagine we rapidly uplift a large chunk of continental lithosphere to make a huge mountain range. This would expose a large volume of rocks, eventually producing small pieces of rock and chemical products, such as bicarbonate, during weathering. These weathering products make their way into streams and eventually oceans.

- a. How would this uplift impact the residence time of CO_2 in the atmosphere?

It would make the residence time of CO_2 in the atmosphere shorter.

- b. Significantly more CO_2 exists in the atmosphere since the industrial revolution and the widespread use of fossil fuels. What has been the impact of this added CO_2 on the weathering rate of rocks found in mountains, monuments, and bricks?

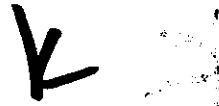
This has caused rock in mountains, monuments & brick to weather at a faster rate.

2. Describe a situation where the size of a reservoir in the carbon cycle is changed and how this impacts the residence time of CO_2 throughout the entire Earth system.

You could cut down a forest & a plant field, taking the ability for the plants to use CO_2 leaving more CO_2 in atmosphere creating a longer residence time.

3. Describe a situation where the residence time for a reservoir in the carbon cycle is changed and how this impacts the residence time of CO_2 throughout the entire Earth system.

The industry could produce more CO_2 releasing it into the atmosphere creating a longer residence time.



Part 3: Homework

If you complete the group work, you may work on the homework on your own. This means your answers should be generally unique from other students' answers. **Submit your homework using ANGEL.**

1. Describe what it means for a reservoir to change size.

changing temp or taking away

2. Describe a situation where the residence time for a reservoir in the carbon cycle is **increased** and how this impacts the residence time of CO₂ throughout the entire Earth system.

forest

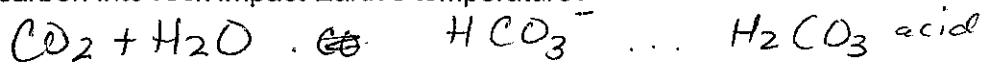
3. Describe a situation where the residence time for a reservoir in the carbon cycle is **decreased** and how this impacts the residence time of CO₂ throughout the entire Earth system.

warm water holds less carbon because it is moving quicker.

4. How does an atom of carbon move from coal into the atmosphere? Explain what would happen to Earth's temperature if the processes that move carbon into the atmosphere slowed down.

burn coal. carbon \rightarrow dioxide.

5. Recall our earlier work with ocean acidification. How does an atom of carbon move from CO₂ in water into rock? How would an increase in the processes that move carbon into rock impact Earth's temperature?



6. Just for fun: How does an atom of carbon move from HCO₃ in water into carbon in limestone your skin?

ISP203A – Global Change Cycles

Objectives

Upon completion of this activity, you will be able to:

- Recognize how carbon moves through the environment.
- Reason about the role of different events in changing CO₂ concentrations in Earth's atmosphere
 - Reason to how this will impact temperature

Causal Principles

1. Gravitational energy, thermal energy and/or chemical energy drive all movement and change of matter on Earth.
2. A system is in equilibrium when energy in the system is balanced.
3. Matter moves and changes to return a system to equilibrium.
4. Energy is needed to break bonds and is released when bonds form.
5. Temperature is a measure of the movement of molecules. Higher temperature means molecules are moving faster.
6. When molecules move faster, the density of most substances decreases. Water is an anomaly because liquid water is more dense than ice.
7. Buoyancy causes materials to rise or fall due to the relative density of materials.
8. Feedback Loops can accelerate, decelerate, or dampen change.

PART 1: Background Notes

Part 1: Class Work

Brainstorm the important reservoirs, processes, and impacts on residence times for the carbon cycle.

Characteristic	Carbon Cycle
Reservoirs	Forests (Biosphere) Ocean (Hydrosphere) CaCO ₃ limestone (Rocks) atmosphere CO ₂ HCO ₃ lithosphere
Processes	weathering, degassing, burial, photosynthesis, respiration burning, ocean acidification
Residence Times	Change flux. Decrease or increase the size of a reservoir decrease flux increase residence time

~~_____~~ A434194348
~~_____~~ A41439593
~~_____~~ A42065731
~~_____~~ A42204525

Part 2: Group Work

A. Make sure everyone in your group understands these terms before moving on.

1. Reservoirs: *where carbon is stored.*
2. Evaporation: *process of changing liquid to gas*
3. Degassing: *The movement of gas from one place to another*
4. Chemical Energy (when is energy used and when is energy released?) *energy is used in weathering and is released when carbon reaches down.*

B. Answer the following questions about the carbon cycle. Try to include your reasoning along with your answer – What evidence do you have to support your answer?

1. What is the largest carbon reservoir? Explain your reasoning.

Biosphere Rocks because they are able to hold the highest concentration of carbon.

2. Which carbon reservoir has the longest residence time? Explain your reasoning.

Rocks because it takes the longest to break them down and move the carbon somewhere else.

3. Which carbon reservoir has the shortest reservoir time? Explain your reasoning.

Atmosphere it moves more quickly from the atmosphere to the earth's surface and then back again

4. Which form of energy is more important for carbon cycle processes, gravitational or chemical? Explain your reasoning.

Chemical because this allows for carbon to change forms and cycle through different reservoirs

5. How is the process of degassing in the carbon cycle different from the process of evaporation in the water cycle?

Degassing is the movement of gas from one place to another like the movement of CO₂ from the ocean to the atmosphere where an evaporation is the change of liquid to gas.

C. Scenario Questions

1. Imagine we rapidly uplift a large chunk of continental lithosphere to make a huge mountain range. This would expose a large volume of rocks, eventually producing small pieces of rock and chemical products, such as bicarbonate, during weathering. These weathering products make their way into streams and eventually oceans.

- a. How would this uplift impact the residence time of CO₂ in the atmosphere?

This would increase the residence time because more CO₂ would be ~~exposed~~ ^{released} to the atmosphere causing it to have a longer residence time.

- b. Significantly more CO₂ exists in the atmosphere since the industrial revolution and the widespread use of fossil fuels. What has been the impact of this added CO₂ on the weathering rate of rocks found in mountains, monuments, and bricks?

They weather faster because the rain is now more acidic.

2. Describe a situation where the size of a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

more CO₂ in the ocean causes the ocean to become more acidic which weakens down the coral reefs releasing more CO₂ to the atmosphere.

3. Describe a situation where the residence time for a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

putting more CO₂ in the atmosphere would increase the residence time which would then increase the residence time throughout the Earth system.



Part 3: Homework

If you complete the group work, you may work on the homework on your own. This means your answers should be generally unique from other students' answers. **Submit your homework using ANGEL.**

1. Describe what it means for a reservoir to change size.
2. Describe a situation where the residence time for a reservoir in the carbon cycle is **increased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
3. Describe a situation where the residence time for a reservoir in the carbon cycle is **decreased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
4. How does an atom of carbon move from coal into the atmosphere? Explain what would happen to Earth's temperature if the processes that move carbon into the atmosphere slowed down.
5. Recall our earlier work with ocean acidification. How does an atom of carbon move from CO₂ in water into rock? How would an increase in the processes that move carbon into rock impact Earth's temperature?
6. Just for fun: How does an atom of carbon move from HCO₃ in water into carbon in your skin?

ISP203A – Global Change Cycles

Objectives

Upon completion of this activity, you will be able to:

- Recognize how carbon moves through the environment.
- Reason about the role of different events in changing CO₂ concentrations in Earth's atmosphere
 - Reason to how this will impact temperature

Causal Principles

1. Gravitational energy, thermal energy and/or chemical energy drive all movement and change of matter on Earth.
2. A system is in equilibrium when energy in the system is balanced.
3. Matter moves and changes to return a system to equilibrium.
4. Energy is needed to break bonds and is released when bonds form.
5. Temperature is a measure of the movement of molecules. Higher temperature means molecules are moving faster.
6. When molecules move faster, the density of most substances decreases. Water is an anomaly because liquid water is more dense than ice.
7. Buoyancy causes materials to rise or fall due to the relative density of materials.
8. Feedback Loops can accelerate, decelerate, or dampen change.

PART 1: Background Notes

Part 1: Class Work

Brainstorm the important reservoirs, processes, and impacts on residence times for the carbon cycle.

Characteristic	Carbon Cycle
Reservoirs	
Processes	
Residence Times	

M

GROUP #: ~~XXXXXX~~
Student IDs of Members Present:

~~XXXXXXXXXX~~ A34305310
~~XXXXXXXXXX~~ A+2383975
~~XXXXXXXXXX~~ A+2772599
~~XXXXXXXXXX~~ A43915317

Part 2: Group Work

A. Make sure everyone in your group understands these terms before moving on.

1. Reservoirs: location in which a material stays
2. Evaporation: Liquid to gas
3. Degassing: gas in a liquid transferring to the atmosphere.
4. Chemical Energy (when is energy used and when is energy released?) - The forming & breaking of chemical bonds.

B. Answer the following questions about the carbon cycle. Try to include your reasoning along with your answer – What evidence do you have to support your answer?

1. What is the largest carbon reservoir? Explain your reasoning.
lithosphere, because the earth is mostly rocks

2. Which carbon reservoir has the longest residence time? Explain your reasoning.
lithosphere, the more C the slower the flux,
which ↑ residence time

3. Which carbon reservoir has the shortest reservoir time? Explain your reasoning.
biosphere because organisms are constantly
"losing" and "gaining" C

4. Which form of energy is more important for carbon cycle processes, gravitational or chemical? Explain your reasoning.
chemical because it involves the changing of bonds
(breaking and forming) more than an "up or down"
motion

5. How is the process of degassing in the carbon cycle different from the process of evaporation in the water cycle?

degassing: gas from the liquid H₂O rising to atmosphere,
gas to gas.

evap: liquid to a gas

M

C. Scenario Questions

1. Imagine we rapidly uplift a large chunk of continental lithosphere to make a huge mountain range. This would expose a large volume of rocks, eventually producing small pieces of rock and chemical products, such as bicarbonate, during weathering. These weathering products make their way into streams and eventually oceans.

a. How would this uplift impact the residence time of CO₂ in the atmosphere?

There would be more in the ocean, so more will degas out into the atmosphere, ↑ the residence time

b. Significantly more CO₂ exists in the atmosphere since the industrial revolution and the widespread use of fossil fuels. What has been the impact of this added CO₂ on the weathering rate of rocks found in mountains, monuments, and bricks?

Acidification of rain weathers rock faster

2. Describe a situation where the size of a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

Chop down trees, biosphere reservoir smaller, flux faster, RT ↓

Shrubland → forest

3. Describe a situation where the residence time for a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

IF RT is shorter in hydrosphere, then it will flux out faster, allowing it to increase the amount in another reservoir, which would in turn ↑ that RT



Part 3: Homework

If you complete the group work, you may work on the homework on your own. This means your answers should be generally unique from other students' answers. **Submit your homework using ANGEL.**

1. Describe what it means for a reservoir to change size.
2. Describe a situation where the residence time for a reservoir in the carbon cycle is **increased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
3. Describe a situation where the residence time for a reservoir in the carbon cycle is **decreased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
4. How does an atom of carbon move from coal into the atmosphere? Explain what would happen to Earth's temperature if the processes that move carbon into the atmosphere slowed down.
5. Recall our earlier work with ocean acidification. How does an atom of carbon move from CO₂ in water into rock? How would an increase in the processes that move carbon into rock impact Earth's temperature?
6. Just for fun: How does an atom of carbon move from HCO₃ in water into carbon in your skin?

N

Objectives

Upon completion of this activity, you will be able to:

- Recognize how carbon moves through the environment.
- Reason about the role of different events in changing CO₂ concentrations in Earth's atmosphere
 - Reason to how this will impact temperature

Causal Principles

1. Gravitational energy, thermal energy and/or chemical energy drive all movement and change of matter on Earth.
2. A system is in equilibrium when energy in the system is balanced.
3. Matter moves and changes to return a system to equilibrium.
4. Energy is needed to break bonds and is released when bonds form.
5. Temperature is a measure of the movement of molecules. Higher temperature means molecules are moving faster.
6. When molecules move faster, the density of most substances decreases. Water is an anomaly because liquid water is more dense than ice.
7. Buoyancy causes materials to rise or fall due to the relative density of materials.
8. Feedback Loops can accelerate, decelerate, or dampen change.

PART 1: Background Notes

Part 1: Class Work

Brainstorm the important reservoirs, processes, and impacts on residence times for the carbon cycle.

Characteristic	Carbon Cycle
Reservoirs	forests, oceans, atmosphere, limestone
Processes	weathering, degassing, burial, photosynthesis, respiration, burning
Residence Times	changing the flux, change reservoir size

Part 2: Group Work

A. Make sure everyone in your group understands these terms before moving on.

1. Reservoirs: *underground holder of water*

2. Evaporation: *Water is converted from liquid to gas*

3. Degassing: *to remove gas from*

4. Chemical Energy (when is energy used and when is energy released?)

Potential of a chemical substance to undergo a transformation through a chemical reaction or to transform other chemical substances

B. Answer the following questions about the carbon cycle. Try to include your reasoning along with your answer – What evidence do you have to support your answer?

1. What is the largest carbon reservoir? Explain your reasoning.

Limestone because dissolved carbon combines w/ dissolved carbonate in the ocean to form limestone.

2. Which carbon reservoir has the longest residence time? Explain your reasoning.

Limestone because it would take longer to weather

3. Which carbon reservoir has the shortest residence time? Explain your reasoning.

plants because plants regrow quickly

4. Which form of energy is more important for carbon cycle processes, gravitational or chemical? Explain your reasoning.

Chemical because there are more chemical reactions

5. How is the process of degassing in the carbon cycle different from the process of evaporation in the water cycle?

degassing it stays a gas while evaporation it phase changes

14

C. Scenario Questions

1. Imagine we rapidly uplift a large chunk of continental lithosphere to make a huge mountain range. This would expose a large volume of rocks, eventually producing small pieces of rock and chemical products, such as bicarbonate, during weathering. These weathering products make their way into streams and eventually oceans.

a. How would this uplift impact the residence time of CO₂ in the atmosphere?

Decrease the residence time
because the influx would be
greater than a flux.

- b. Significantly more CO₂ exists in the atmosphere since the industrial revolution and the widespread use of fossil fuels. What has been the impact of this added CO₂ on the weathering rate of rocks found in mountains, monuments, and bricks?

There would be more acid
rain which would result
in weathering rate increasing

2. Describe a situation where the size of a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

warm water results in a smaller
reservoir because warm water can't
hold as much + this speeds up the
cycle

3. Describe a situation where the residence time for a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

when the water is warm, the
reservoir is smaller which means
smaller residence time + this
speeds up the cycle

N

Part 3: Homework

If you complete the group work, you may work on the homework on your own. This means your answers should be generally unique from other students' answers. **Submit your homework using ANGEL.**

1. Describe what it means for a reservoir to change size.
2. Describe a situation where the residence time for a reservoir in the carbon cycle is **increased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
3. Describe a situation where the residence time for a reservoir in the carbon cycle is **decreased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
4. How does an atom of carbon move from coal into the atmosphere? Explain what would happen to Earth's temperature if the processes that move carbon into the atmosphere slowed down.
5. Recall our earlier work with ocean acidification. How does an atom of carbon move from CO₂ in water into rock? How would an increase in the processes that move carbon into rock impact Earth's temperature?
6. Just for fun: How does an atom of carbon move from HCO₃ in water into carbon in your skin?

ISP203A – Global Change Cycles

Objectives

Upon completion of this activity, you will be able to:

- Recognize how carbon moves through the environment.
- Reason about the role of different events in changing CO₂ concentrations in Earth's atmosphere
 - Reason to how this will impact temperature

Causal Principles

1. Gravitational energy, thermal energy and/or chemical energy drive all movement and change of matter on Earth.
2. A system is in equilibrium when energy in the system is balanced.
3. Matter moves and changes to return a system to equilibrium.
4. Energy is needed to break bonds and is released when bonds form.
5. Temperature is a measure of the movement of molecules. Higher temperature means molecules are moving faster.
6. When molecules move faster, the density of most substances decreases. Water is an anomaly because liquid water is more dense than ice.
7. Buoyancy causes materials to rise or fall due to the relative density of materials.
8. Feedback Loops can accelerate, decelerate, or dampen change.

PART 1: Background Notes

RESERVOIRS → where things are stored

FLUXES → movement in/out of reservoir

residence time → how long something stays

Part 1: Class Work

Brainstorm the important reservoirs, processes, and impacts on residence times for the carbon cycle.

Characteristic	Carbon Cycle
Reservoirs	hydrosphere oceans, forests (biomass), limestone (rocks) atmosphere biosphere
Processes	weathering, degassing (ocean → atmosphere) burial, photosynthesis, respiration, burning ocean acidification
Residence Times	change flux, change size of reservoir, decrease reservoir → decrease R.T. decrease flux → increase R.T.

GROUP #: 0

Student IDs of Members Present:

A43643320 A41262816

A41096642

A3450917

Part 2: Group Work

A. Make sure everyone in your group understands these terms before moving on.

1. Reservoirs: ~~where~~ things are stored
2. Evaporation: the change from a liquid to gas.
3. Degassing: the movement of a gas in water, to the atmosphere.
4. Chemical Energy (when is energy used and when is energy released?)
energy is used to break bonds & released when bonds are formed.

B. Answer the following questions about the carbon cycle. Try to include your reasoning along with your answer – What evidence do you have to support your answer?

1. What is the largest carbon reservoir? Explain your reasoning.

Rocks like limestone because it has trapped carbon & covers large areas of the earth.

2. Which carbon reservoir has the longest residence time? Explain your reasoning.

Limestone (lithosphere) because it traps carbon in bonds & doesn't release it to the atmosphere/oceans.

3. Which carbon reservoir has the shortest reservoir time? Explain your reasoning.

The atmosphere because it has a fluctuating flux of carbon from photosynthesis, respiration & ocean acidification.

4. Which form of energy is more important for carbon cycle processes, gravitational or chemical? Explain your reasoning. Chemical energy is most important because bonds are constantly being formed & broken as carbon moves through the atmosphere, ocean, & lithosphere & plant material.

5. How is the process of degassing in the carbon cycle different from the process of evaporation in the water cycle?

degassing is the movement of gas from water, to the atmosphere, evaporation is the change from a liquid to a gas.

A

C. Scenario Questions

1. Imagine we rapidly uplift a large chunk of continental lithosphere to make a huge mountain range. This would expose a large volume of rocks, eventually producing small pieces of rock and chemical products, such as bicarbonate, during weathering. These weathering products make their way into streams and eventually oceans.

a. How would this uplift impact the residence time of CO₂ in the atmosphere?

Some of the CO₂ in the rocks would eventually end up in the ocean which would degas into the atmosphere making the residence time increase.

b. Significantly more CO₂ exists in the atmosphere since the industrial revolution and the widespread use of fossil fuels. What has been the impact of this added CO₂ on the weathering rate of rocks found in mountains, monuments, and bricks?

More CO₂ mixes with hydrogen in rain & creates acid rain which increases the rate of weathering on marble & limestone.

2. Describe a situation where the size of a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

If a reservoir like a lake decreases the residence time would decrease meaning there would be a greater amount of CO₂ in the atmosphere which would add more greenhouse gases & cause temperature to increase.

3. Describe a situation where the residence time for a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

If residence time goes down in oceans then seashells wouldn't form as much which would cause organisms to not be able to live off them which could lead to a collapse of fisheries.



Part 3: Homework

If you complete the group work, you may work on the homework on your own. This means your answers should be generally unique from other students' answers. **Submit your homework using ANGEL.**

1. Describe what it means for a reservoir to change size.
2. Describe a situation where the residence time for a reservoir in the carbon cycle is **increased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
3. Describe a situation where the residence time for a reservoir in the carbon cycle is **decreased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
4. How does an atom of carbon move from coal into the atmosphere? Explain what would happen to Earth's temperature if the processes that move carbon into the atmosphere slowed down.
5. Recall our earlier work with ocean acidification. How does an atom of carbon move from CO₂ in water into rock? How would an increase in the processes that move carbon into rock impact Earth's temperature?
6. Just for fun: How does an atom of carbon move from HCO₃ in water into carbon in your skin?

p

Objectives

Upon completion of this activity, you will be able to:

- Recognize how carbon moves through the environment.
- Reason about the role of different events in changing CO₂ concentrations in Earth's atmosphere
 - Reason to how this will impact temperature

Causal Principles

1. Gravitational energy, thermal energy and/or chemical energy drive all movement and change of matter on Earth.
2. A system is in equilibrium when energy in the system is balanced.
3. Matter moves and changes to return a system to equilibrium.
4. Energy is needed to break bonds and is released when bonds form.
5. Temperature is a measure of the movement of molecules. Higher temperature means molecules are moving faster.
6. When molecules move faster, the density of most substances decreases. Water is an anomaly because liquid water is more dense than ice.
7. Buoyancy causes materials to rise or fall due to the relative density of materials.
8. Feedback Loops can accelerate, decelerate, or dampen change.

PART 1: Background Notes

Part 1: Class Work

Brainstorm the important reservoirs, processes, and impacts on residence times for the carbon cycle.

Characteristic	Carbon Cycle
Reservoirs	
Processes	
Residence Times	

Part 2: Group Work

A. Make sure everyone in your group understands these terms before moving on.

1. Reservoirs:
2. Evaporation:
3. Degassing:
4. Chemical Energy (when is energy used and when is energy released?)

B. Answer the following questions about the carbon cycle. Try to include your reasoning along with your answer – What evidence do you have to support your answer?

1. What is the largest carbon reservoir? Explain your reasoning.
2. Which carbon reservoir has the longest residence time? Explain your reasoning.
3. Which carbon reservoir has the shortest reservoir time? Explain your reasoning.
4. Which form of energy is more important for carbon cycle processes, gravitational or chemical? Explain your reasoning.
5. How is the process of degassing in the carbon cycle different from the process of evaporation in the water cycle?



C. Scenario Questions

1. Imagine we rapidly uplift a large chunk of continental lithosphere to make a huge mountain range. This would expose a large volume of rocks, eventually producing small pieces of rock and chemical products, such as bicarbonate, during weathering. These weathering products make their way into streams and eventually oceans.
 - a. How would this uplift impact the residence time of CO₂ in the atmosphere?

 - b. Significantly more CO₂ exists in the atmosphere since the industrial revolution and the widespread use of fossil fuels. What has been the impact of this added CO₂ on the weathering rate of rocks found in mountains, monuments, and bricks?

2. Describe a situation where the size of a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

3. Describe a situation where the residence time for a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

Part 3: Homework

If you complete the group work, you may work on the homework on your own. This means your answers should be generally unique from other students' answers. **Submit your homework using ANGEL.**

1. Describe what it means for a reservoir to change size.
2. Describe a situation where the residence time for a reservoir in the carbon cycle is **increased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
3. Describe a situation where the residence time for a reservoir in the carbon cycle is **decreased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
4. How does an atom of carbon move from coal into the atmosphere? Explain what would happen to Earth's temperature if the processes that move carbon into the atmosphere slowed down.
5. Recall our earlier work with ocean acidification. How does an atom of carbon move from CO₂ in water into rock? How would an increase in the processes that move carbon into rock impact Earth's temperature?
6. Just for fun: How does an atom of carbon move from HCO₃ in water into carbon in your skin?

ISP203A – Global Change Cycles



Objectives

Upon completion of this activity, you will be able to:

- Recognize how carbon moves through the environment.
- Reason about the role of different events in changing CO₂ concentrations in Earth's atmosphere
 - Reason to how this will impact temperature

Causal Principles

1. Gravitational energy, thermal energy and/or chemical energy drive all movement and change of matter on Earth.
2. A system is in equilibrium when energy in the system is balanced.
3. Matter moves and changes to return a system to equilibrium.
4. Energy is needed to break bonds and is released when bonds form.
5. Temperature is a measure of the movement of molecules. Higher temperature means molecules are moving faster.
6. When molecules move faster, the density of most substances decreases. Water is an anomaly because liquid water is more dense than ice.
7. Buoyancy causes materials to rise or fall due to the relative density of materials.
8. Feedback Loops can accelerate, decelerate, or dampen change.

PART 1: Background Notes

Part 1: Class Work

Brainstorm the important reservoirs, processes, and impacts on residence times for the carbon cycle.

Characteristic	Carbon Cycle
Reservoirs	forests (biomass), limestone, oceans, atmosphere
Processes	weathering, degassing, burial, photosynthesis, respiration, burning, ocean acidification
Residence Times	change flux, change size reservoir, decrease reservoir size, decrease time.

Part 2: Group Work

A. Make sure everyone in your group understands these terms before moving on.

1. Reservoirs:

where matter is stored

2. Evaporation:

3. Degassing:

4. Chemical Energy (when is energy used and when is energy released?)

B. Answer the following questions about the carbon cycle. Try to include your reasoning along with your answer – What evidence do you have to support your answer?

1. What is the largest carbon reservoir? Explain your reasoning.

limestone

2. Which carbon reservoir has the longest residence time? Explain your reasoning.

lithosphere; when you bury something it just sits there forever

3. Which carbon reservoir has the shortest reservoir time? Explain your reasoning.

~~lithosphere~~ biosphere

4. Which form of energy is more important for carbon cycle processes, gravitational or chemical? Explain your reasoning.

5. How is the process of degassing in the carbon cycle different from the process of evaporation in the water cycle?

Q

C. Scenario Questions

1. Imagine we rapidly uplift a large chunk of continental lithosphere to make a huge mountain range. This would expose a large volume of rocks, eventually producing small pieces of rock and chemical products, such as bicarbonate, during weathering. These weathering products make their way into streams and eventually oceans.

- a. How would this uplift impact the residence time of CO₂ in the atmosphere?

The residence time ^{of carbon} would increase.

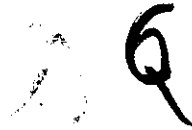
- b. Significantly more CO₂ exists in the atmosphere since the industrial revolution and the widespread use of fossil fuels. What has been the impact of this added CO₂ on the weathering rate of rocks found in mountains, monuments, and bricks?

The weathering rate of rocks will increase with more CO₂

2. Describe a situation where the size of a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

Deforestation will decrease residence time

3. Describe a situation where the residence time for a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.



Part 3: Homework

If you complete the group work, you may work on the homework on your own. This means your answers should be generally unique from other students' answers. **Submit your homework using ANGEL.**

1. Describe what it means for a reservoir to change size.
2. Describe a situation where the residence time for a reservoir in the carbon cycle is **increased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
3. Describe a situation where the residence time for a reservoir in the carbon cycle is **decreased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
4. How does an atom of carbon move from coal into the atmosphere? Explain what would happen to Earth's temperature if the processes that move carbon into the atmosphere slowed down.
5. Recall our earlier work with ocean acidification. How does an atom of carbon move from CO₂ in water into rock? How would an increase in the processes that move carbon into rock impact Earth's temperature?
6. Just for fun: How does an atom of carbon move from HCO₃ in water into carbon in your skin?

ISP203A – Global Change
Cycles

Objectives

Upon completion of this activity, you will be able to:

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- Reason about the role of different events in changing CO₂ concentrations in Earth's atmosphere
 - Reason to how this will impact temperature

Causal Principles

1. Gravitational energy, thermal energy and/or chemical energy drive all movement and change of matter on Earth.
2. A system is in equilibrium when energy in the system is balanced.
3. Matter moves and changes to return a system to equilibrium.
4. Energy is needed to break bonds and is released when bonds form.
5. Temperature is a measure of the movement of molecules. Higher temperature means molecules are moving faster.
6. When molecules move faster, the density of most substances decreases. Water is an anomaly because liquid water is more dense than ice.
7. Buoyancy causes materials to rise or fall due to the relative density of materials.
8. Feedback Loops can accelerate, decelerate, or dampen change.

PART 1: Background Notes

Part 1: Class Work

Brainstorm the important reservoirs, processes, and impacts on residence times for the carbon cycle.

Characteristic	Carbon Cycle
Reservoirs	
Processes	
Residence Times	

GROUP #: **R**

Student IDs of Members Present:

K → A39979826 A40994271
J → A40711436
K → A40688430

Part 2: Group Work

A. Make sure everyone in your group understands these terms before moving on.

1. Reservoirs:

An artificial lake used to store water

Forests, limestones, oceans, atmosphere (carbon cycle)

2. Evaporation:

vaporization of a liquid that occurs only on the surface of a liquid
water is converted from its liquid to vapor form

3. Degassing:

The removal of gas

the diffusion of CO_2 into water → process showing ocean acidification

4. Chemical Energy (when is energy used and when is energy released?)

Reactions that occur in chemical compounds,
when energy is released (from heat) we can harvest it as power
to use in our everyday lives

B. Answer the following questions about the carbon cycle. Try to include your reasoning along with your answer – What evidence do you have to support your answer?

1. What is the largest carbon reservoir? Explain your reasoning.

The largest reservoir of carbon is limestone.
In the carbon cycle, carbon dioxide is released when limestone
which is calcium carbonate is released to produce lime (calcium
oxide)

2. Which carbon reservoir has the longest residence time? Explain your reasoning.

Sedimentary limestone is preserved for millions
of years. Limestone and other carbonate rocks hold the majority
of carbon on the planet as well

3. Which carbon reservoir has the shortest reservoir time? Explain your reasoning.

Plants because they generally have short lifespans, often only
annual cycle. The oldest plants are only a few thousand years old
and older plants are an insignificant part of the plant carbon

4. Which form of energy is more important for carbon cycle processes, gravitational or chemical? Explain your reasoning.

Chemical is because the carbon cycle is a set of biochemical
process in which carbon undergoes chemical reactions and
changes form

5. How is the process of degassing in the carbon cycle different from the process of evaporation in the water cycle?

Degassing is where CO_2 is released into the atmosphere
 CO_2 is a gas in the water, and moves into the atmosphere.
Evaporation is not a gas ^{carbon} vapor

evap - liquid to gas. CO_2 in ocean moving
into the oceans
 CO_2 is gas in ocean - when moves
move of gas transferred into atmosphere

Small reservoir = ↓ residence time
↓ Flux = ↑ residence time

C. Scenario Questions

1. Imagine we rapidly uplift a large chunk of continental lithosphere to make a huge mountain range. This would expose a large volume of rocks, eventually producing small pieces of rock and chemical products, such as bicarbonate, during weathering. These weathering products make their way into streams and eventually oceans.

a. How would this uplift impact the residence time of CO₂ in the atmosphere?
Residence time would decrease because the flux is increasing therefore decreasing residence time

- b. Significantly more CO₂ exists in the atmosphere since the industrial revolution and the widespread use of fossil fuels. What has been the impact of this added CO₂ on the weathering rate of rocks found in mountains, monuments, and bricks?

Since CO₂ is a main compound in weathering this will have a ^{neg.} positive impact on mtns, monuments & bricks. By negative I mean that weathering will be more frequent and faster of a process.

2. Describe a situation where the size of a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

If the reservoir is decreased in size, the residence time is decreased.

3. Describe a situation where the residence time for a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

More trees are being cut down therefore more CO₂ is being released into the atmosphere by the process of burning. Increased the flux so this in turn will decrease the residence time.

ISP203A – Global Change
Cycles

Part 3: Homework

If you complete the group work, you may work on the homework **on your own**. This means your answers should be generally unique from other students' answers. **Submit your homework using ANGEL.**

1. Describe what it means for a reservoir to change size.
2. Describe a situation where the residence time for a reservoir in the carbon cycle is **increased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
3. Describe a situation where the residence time for a reservoir in the carbon cycle is **decreased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
4. How does an atom of carbon move from coal into the atmosphere? Explain what would happen to Earth's temperature if the processes that move carbon into the atmosphere slowed down.
5. Recall our earlier work with ocean acidification. How does an atom of carbon move from CO₂ in water into rock? How would an increase in the processes that move carbon into rock impact Earth's temperature?
6. Just for fun: How does an atom of carbon move from HCO₃ in water into carbon in your skin?



Objectives

Upon completion of this activity, you will be able to:

- Recognize how carbon moves through the environment.
- Reason about the role of different events in changing CO₂ concentrations in Earth's atmosphere
 - Reason to how this will impact temperature

Causal Principles

1. Gravitational energy, thermal energy and/or chemical energy drive all movement and change of matter on Earth.
2. A system is in equilibrium when energy in the system is balanced.
3. Matter moves and changes to return a system to equilibrium.
4. Energy is needed to break bonds and is released when bonds form.
5. Temperature is a measure of the movement of molecules. Higher temperature means molecules are moving faster.
6. When molecules move faster, the density of most substances decreases. Water is an anomaly because liquid water is more dense than ice.
7. Buoyancy causes materials to rise or fall due to the relative density of materials.
8. Feedback Loops can accelerate, decelerate, or dampen change.

PART 1: Background Notes

Part 1: Class Work

Brainstorm the important reservoirs, processes, and impacts on residence times for the carbon cycle.

Characteristic	Carbon Cycle CO₂, CO₃, HCO₃⁻ ↑
Reservoirs	FORESTS (BIOSPHERE), LIMESTONE (ROCKS), OCEANS (HYDROSPHERE), ATMOSPHERE
Processes	WEATHERING, DEGASSING, BURIAL, PHOTOSYNTHESIS, RESPIRATION, BURNING, OCEAN ACIDIFICATION,
Residence Times	CHANGE FLUX, CHANGE SIZE OF RESERVOIR – DECREASE, LESS RESIDENCE TIME ↑ OUT OF RESERVOIR DECREASE FLUX, INCREASE RESIDENCE TIME

GROUP #: 5
Student IDs of Members Present:
A43292970
A13927449
A43294133
A43856550

Part 2: Group Work

A. Make sure everyone in your group understands these terms before moving on.

1. Reservoirs:

Places where matter is stored.

2. Evaporation:

Process of changing a substance from liquid to gas.

3. Degassing:

Moving gasses from one reservoir to another

4. Chemical Energy (when is energy used and when is energy released?)

Using energy to break bonds, releasing energy when they form

B. Answer the following questions about the carbon cycle. Try to include your reasoning along with your answer – What evidence do you have to support your answer?

1. What is the largest carbon reservoir? Explain your reasoning.

Limestones; because it has a long residence time and carbon accumulates over time. (Burial)

2. Which carbon reservoir has the longest residence time? Explain your reasoning.

Limestones; because carbon builds up in limestones through the process of burial.

3. Which carbon reservoir has the shortest reservoir time? Explain your reasoning.

Biosphere; Carbon moves back and forth between the biosphere and atmosphere through the processes of respiration and photosynthesis

4. Which form of energy is more important for carbon cycle processes, gravitational or chemical? Explain your reasoning.

Chemical; because it's constantly changing its composition

5. How is the process of degassing in the carbon cycle different from the process of evaporation in the water cycle?

Evaporation describes how water changes from a liquid to a gas and degassing is when a gas moves from one reservoir to another



C. Scenario Questions

1. Imagine we rapidly uplift a large chunk of continental lithosphere to make a huge mountain range. This would expose a large volume of rocks, eventually producing small pieces of rock and chemical products, such as bicarbonate, during weathering. These weathering products make their way into streams and eventually oceans.

- a. How would this uplift impact the residence time of CO₂ in the atmosphere?

The residence ^{time} is longer in the atmosphere because of flux. More weathering from uplift causes more CO₂ to be released into the atmosphere. This causes an increase in the inflow, so residence time is longer.

- b. Significantly more CO₂ exists in the atmosphere since the industrial revolution and the widespread use of fossil fuels. What has been the impact of this added CO₂ on the weathering rate of rocks found in mountains, monuments, and bricks?

More CO₂ causes more weathering, so the weathering rate increases.

2. Describe a situation where the size of a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

Cutting down forests reduces the size of the biomass reservoir. This means that less CO₂ is leaving the atmosphere to the biosphere. The outflow of CO₂ from the atmosphere decreases, causing a longer residence time in the atmosphere.

3. Describe a situation where the residence time for a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

Burning trees increases the inflow of carbon into the atmosphere. That increases the ~~flow~~ residence time of carbon in the atmosphere...



Part 3: Homework

If you complete the group work, you may work on the homework on your own. This means your answers should be generally unique from other students' answers. **Submit your homework using ANGEL.**

1. Describe what it means for a reservoir to change size.
2. Describe a situation where the residence time for a reservoir in the carbon cycle is **increased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
3. Describe a situation where the residence time for a reservoir in the carbon cycle is **decreased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
4. How does an atom of carbon move from coal into the atmosphere? Explain what would happen to Earth's temperature if the processes that move carbon into the atmosphere slowed down.
5. Recall our earlier work with ocean acidification. How does an atom of carbon move from CO₂ in water into rock? How would an increase in the processes that move carbon into rock impact Earth's temperature?
6. Just for fun: How does an atom of carbon move from HCO₃ in water into carbon in your skin?

ISP203A – Global Change Cycles

Objectives

Upon completion of this activity, you will be able to:

- Recognize how carbon moves through the environment.
- Reason about the role of different events in changing CO₂ concentrations in Earth's atmosphere
 - Reason to how this will impact temperature

Causal Principles

1. Gravitational energy, thermal energy and/or chemical energy drive all movement and change of matter on Earth.
2. A system is in equilibrium when energy in the system is balanced.
3. Matter moves and changes to return a system to equilibrium.
4. Energy is needed to break bonds and is released when bonds form.
5. Temperature is a measure of the movement of molecules. Higher temperature means molecules are moving faster.
6. When molecules move faster, the density of most substances decreases. Water is an anomaly because liquid water is more dense than ice.
7. Buoyancy causes materials to rise or fall due to the relative density of materials.
8. Feedback Loops can accelerate, decelerate, or dampen change.

PART 1: Background Notes

Part 1: Class Work

Brainstorm the important reservoirs, processes, and impacts on residence times for the carbon cycle.

Characteristic	Carbon Cycle
Reservoirs	
Processes	
Residence Times	

scan specification → acid rain
water in the presence of CO₂ → sorry

Part 2: Group Work

A. Make sure everyone in your group understands these terms before moving on.

1. Reservoirs: an artificial or natural water base used for regulation & storage of water, an underground accumulation of ~~precipitation~~ carbon.
2. Evaporation: To convert or change into a vapor, to draw off in the form of vapor, to draw moisture from ~~by~~ heats, leaving only to dry solid portions.
3. Degassing: diffusing of CO₂, the process by which dissolved gas is removed from water or other liquid solutions.
4. Chemical Energy (when is energy used and when is energy released?) the potential of a chemical substance to undergo a transformation through a chemical reaction or to transform other chemical substances.

B. Answer the following questions about the carbon cycle. Try to include your reasoning along with your answer – What evidence do you have to support your answer?

1. What is the largest carbon reservoir? Explain your reasoning.

Limestone because it is made up of all the dead organic material

2. Which carbon reservoir has the longest residence time? Explain your reasoning.

Residence time is how long it stays in the the smaller reservoir, if you decrease reservoirs residence time ~~the smaller the reservoir~~ the reservoir the less residence time so the reservoir with the longest residence time would be the

3. Which carbon reservoir has the shortest reservoir time? Explain your reasoning. atmosphere
Biomass because the smaller the reservoir the shorter the residence time.

4. Which form of energy is more important for carbon cycle processes, gravitational or chemical? Explain your reasoning.

Chemical because there are more phase changes that use chemical energy than gravitational energy.

5. How is the process of degassing in the carbon cycle different from the process of evaporation in the water cycle?

when the degassing processes happens in the carbon cycle carbon is being transferred from one reservoir to another.

C. Scenario Questions

1. Imagine we rapidly uplift a large chunk of continental lithosphere to make a huge mountain range. This would expose a large volume of rocks, eventually producing small pieces of rock and chemical products, such as bicarbonate, during weathering. These weathering products make their way into streams and eventually oceans.

- a. How would this uplift impact the residence time of CO₂ in the atmosphere?

we are building a mountain erosion happens & weathering happens when weathering happens CO₂ is being released & pulling them out of the atmosphere.

- b. Significantly more CO₂ exists in the atmosphere since the industrial revolution and the widespread use of fossil fuels. What has been the impact of this added CO₂ on the weathering rate of rocks found in mountains, monuments, and bricks?

the more CO₂ that is the atmosphere the more acid rain that is produced & the more weathering happens

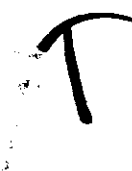
2. Describe a situation where the size of a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

If there is a pond & the pond dries up so the residence time is depleted

3. Describe a situation where the residence time for a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

there is a stream & some limestone rock erode & weather this causes an increase in CO₂ & more CO₂ is pulled out of the atmosphere but is also being released which is a positive feedback loop

build a
mountain
erode mountain
converts CO₂
of atmosphere



Part 3: Homework

If you complete the group work, you may work on the homework on your own. This means your answers should be generally unique from other students' answers. **Submit your homework using ANGEL.**

1. Describe what it means for a reservoir to change size.
2. Describe a situation where the residence time for a reservoir in the carbon cycle is **increased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
3. Describe a situation where the residence time for a reservoir in the carbon cycle is **decreased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
4. How does an atom of carbon move from coal into the atmosphere? Explain what would happen to Earth's temperature if the processes that move carbon into the atmosphere slowed down.
5. Recall our earlier work with ocean acidification. How does an atom of carbon move from CO₂ in water into rock? How would an increase in the processes that move carbon into rock impact Earth's temperature?
6. Just for fun: How does an atom of carbon move from HCO₃ in water into carbon in your skin?

ISP203A – Global Change Cycles

Objectives

Upon completion of this activity, you will be able to:

- Recognize how carbon moves through the environment.
- Reason about the role of different events in changing CO₂ concentrations in Earth's atmosphere
 - Reason to how this will impact temperature

Causal Principles

1. Gravitational energy, thermal energy and/or chemical energy drive all movement and change of matter on Earth.
2. A system is in equilibrium when energy in the system is balanced.
3. Matter moves and changes to return a system to equilibrium.
4. Energy is needed to break bonds and is released when bonds form.
5. Temperature is a measure of the movement of molecules. Higher temperature means molecules are moving faster.
6. When molecules move faster, the density of most substances decreases. Water is an anomaly because liquid water is more dense than ice.
7. Buoyancy causes materials to rise or fall due to the relative density of materials.
8. Feedback Loops can accelerate, decelerate, or dampen change.

PART 1: Background Notes

Volcanos release CO₂ into Atmosphere
 CaCO₃ - Calcium Carbonate - limestone/shells

Part 1: Class Work

Brainstorm the important reservoirs, processes, and impacts on residence times for the carbon cycle.

Characteristic	Carbon Cycle
Reservoirs	Forest (Biomass), limestone (rock), oceans (hydrosphere) atmosphere (gas), rock (CaCO ₃), HCO ₃ (bicarbonate)
Processes	weathering, degassing, burial, bio sphere to land photosynthesis, respiration, burning (releasing CO ₂)
Residence Times	how long stays in res. CO ₂ , (charge from)

ocean (many forms of calcium)
ocean acid from

(Charge Reservoir)

Smaller reservoir = less R.T.
 Decrease flux ~~into~~ Reservoir = longer R.T.
 Out

Part 2: Group Work

A. Make sure everyone in your group understands these terms before moving on.

1. Reservoirs: ~~about where water is stored~~
2. Evaporation: liquid to a gas
3. Degassing: moving a gas from one reservoir to another
4. Chemical Energy (when is energy used and when is energy released?)

When a molecule changes into a different form and molecule

B. Answer the following questions about the carbon cycle. Try to include your reasoning ^{comparing} along with your answer – What evidence do you have to support your answer?

1. What is the largest carbon reservoir? Explain your reasoning.

The ocean. Carbon is in the ocean in many forms, like bicarbonate ions, ~~in dissolved~~ ^{as} Biosphere

2. Which carbon reservoir has the longest residence time? Explain your reasoning.

^{because} ^{longer} Rocks, limestone, ~~and~~ ^{as} ⁱⁿ ^{the} ^{ocean} ^{then} ^{carbon} ^{into} ^{calcium} ^{carbonate} ^{the} ^{use} ^{than} ^{shells} ^{until} ^{they} ^{die}

3. Which carbon reservoir has the shortest reservoir time? Explain your reasoning.

Biosphere – B.T. is lower b/c the form is always changing.

4. Which form of energy is more important for carbon cycle processes, gravitational or chemical? Explain your reasoning.

Chemical, because carbon ~~is~~ ^{changes} ^{forms} ^{often} ^{such} ^{as} ^{through} ^{ocean} ^{acidification} ^{when} ^{it} ^{take} ^{more} ^{than} ³ ^{forms}

5. How is the process of degassing in the carbon cycle different from the process of evaporation in the water cycle?

degassing is a gas in one reservoir going to a gas in the atmosphere.

Evaporation is a liquid going into a gas.

X

C. Scenario Questions

1. Imagine we rapidly uplift a large chunk of continental lithosphere to make a huge mountain range. This would expose a large volume of rocks, eventually producing small pieces of rock and chemical products, such as bicarbonate, during weathering. These weathering products make their way into streams and eventually oceans.

- a. How would this uplift impact the residence time of CO₂ in the atmosphere?

This scenario would be increasing the flux into a reservoir meaning the residence time will increase.

- b. Significantly more CO₂ exists in the atmosphere since the industrial revolution and the widespread use of fossil fuels. What has been the impact of this added CO₂ on the weathering rate of rocks found in mountains, monuments, and bricks?

because more carbonic acid is formed more weathering on rocks will happen

2. Describe a situation where the size of a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

if increase the reservoir for organisms will lower the other reservoir

3. Describe a situation where the residence time for a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

The more carbon going into the air increases the amount that comes out meaning oceans will be getting more carbon, meaning more carbonate ions and acid will be in the ocean making them more acidic.

X

Part 3: Homework

If you complete the group work, you may work on the homework on your own. This means your answers should be generally unique from other students' answers. **Submit your homework using ANGEL.**

1. Describe what it means for a reservoir to change size.

May 2002

2. Describe a situation where the residence time for a reservoir in the carbon cycle is **increased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
3. Describe a situation where the residence time for a reservoir in the carbon cycle is **decreased** and how this impacts the residence time of CO₂ throughout the entire Earth system.
4. How does an atom of carbon move from coal into the atmosphere? Explain what would happen to Earth's temperature if the processes that move carbon into the atmosphere slowed down.
5. Recall our earlier work with ocean acidification. How does an atom of carbon move from CO₂ in water into rock? How would an increase in the processes that move carbon into rock impact Earth's temperature?
6. Just for fun: How does an atom of carbon move from HCO₃ in water into carbon in your skin?

ISP203A – Global Change
Cycles

Objectives

Upon completion of this activity, you will be able to:

- Recognize how carbon moves through the environment.
- Reason about the role of different events in changing CO₂ concentrations in Earth's atmosphere
 - Reason to how this will impact temperature

Causal Principles

1. Gravitational energy, thermal energy and/or chemical energy drive all movement and change of matter on Earth.
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7. Buoyancy causes materials to rise or fall due to the relative density of materials.
8. Feedback Loops can accelerate, decelerate, or dampen change.

PART 1: Background Notes

Part 1: Class Work

Brainstorm the important reservoirs, processes, and impacts on residence times for the carbon cycle.

Characteristic	Carbon Cycle
Reservoirs	Limestone, humans, plants (Biomass), oceans, atmosphere (CO ₂ , CH ₄) Bio, Atm, lith, hydro carbonic acid (CO ₃ ²⁻) (gas, HCO ₃)
Processes	Weathering, degassing (From ocean → atmosphere), burial, photosynthesis, respiration, burning (of biomass), ocean acidification
Residence Times	Change flux, change size of reservoir,

Part 2: Group Work

A. Make sure everyone in your group understands these terms before moving on.

1. Reservoirs: Storage of something (carbon) in a place
2. Evaporation: Change from liquid to a gas.
3. Degassing: Movement of a gas molecule from being dissolved in a liquid to being dissolved in a gas.
4. Chemical Energy (when is energy used and when is energy released?)

B. Answer the following questions about the carbon cycle. Try to include your reasoning along with your answer – What evidence do you have to support your answer?

1. What is the largest carbon reservoir? Explain your reasoning.
Limestone. Rocks are the largest reservoir, and the most carbon moves through it.
2. Which carbon reservoir has the longest residence time? Explain your reasoning.
Limestone. Biological stuff lives much shorter than rocks, and the ocean & atmosphere fluxuate carbon between each other. Burying the carbon in lithosphere ~~residence~~ keeps it the longest.
3. Which carbon reservoir has the shortest ~~reservoir~~ time? Explain your reasoning.
Biomass. Carbon in these reservoirs only lasts as long as the plants/animals do.
4. Which form of energy is more important for carbon cycle processes, gravitational or chemical? Explain your reasoning.
Chemical. Almost all reservoirs use chemical for the carbon cycle. The ones that don't use the other reservoirs for their process.
5. How is the process of degassing in the carbon cycle different from the process of evaporation in the water cycle?
There is no phase change in degassing.

C. Scenario Questions

1. Imagine we rapidly uplift a large chunk of continental lithosphere to make a huge mountain range. This would expose a large volume of rocks, eventually producing small pieces of rock and chemical products, such as bicarbonate, during weathering. These weathering products make their way into streams and eventually oceans.

- a. How would this uplift impact the residence time of CO₂ in the atmosphere?

There would be an increase in residence time, because there is more carbon being weathered. This puts more carbon in the atmosphere, while not changing the size of the reservoir.

- b. Significantly more CO₂ exists in the atmosphere since the industrial revolution and the widespread use of fossil fuels. What has been the impact of this added CO₂ on the weathering rate of rocks found in mountains, monuments, and bricks?

It would increase the weathering rate, since there is more CO₂, which means more acid

2. Describe a situation where the size of a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

Biosphere - massive dying / burial.

impacts RT of -

(Lithosphere - Reduce

Ocean - Reduce

Atmosphere - Reduce (↓ flux)

3. Describe a situation where the residence time for a reservoir in the carbon cycle is changed and how this impacts the residence time of CO₂ throughout the entire Earth system.

Burning Fuel adds CO₂ to the atmosphere, inc. residence time.

This will inc RT of oceans. Extracting coal reduces reservoir size, reducing RT.